PRICE STICKINESS AND INFLATION

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March 1995

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Reserve Bank of Australia

We are grateful to seminar participants at the Reserve Bank, A.N.U., Bond University, Melbourne University, 1994 Conference of Economists and to Palle Andersen, Laurence Ball and Bill Russell for helpful comments. All remaining errors are our own. The views expressed are those of the authors and do not necessarily reflect the views of the Reserve Bank of Australia.

ABSTRACT

A recent model of firms' pricing behaviour by Laurence Ball and Gregory Mankiw has novel implications for the effect of relative price shocks on inflation. This paper examines these implications and establishes the importance of expected inflation for this story. We derive the model relationship between expected inflation, the economy-wide distribution of industry price changes and actual inflation, and show that both Australian and US industry-price data strongly support this derived relationship.

The inflationary impact of relative price shocks depends strongly on expected inflation. When expected inflation is high, a rise in the economy-wide dispersion of shocks is inflationary in the short-run. By contrast, when expected inflation is low, a rise in the dispersion of shocks has minimal impact on inflation. Economy-wide relative price shocks, like terms of trade shocks, are an unavoidable feature of the economic landscape. Their disruptive effect on inflation is minimal, however, when average inflation, and therefore average expected inflation, is kept low.

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1. INTRODUCTION

The idea that nominal prices and wages are sticky was one of the foundation-stones upon which the discipline of macroeconomics was built. This stickiness of prices and wages is of more than idle concern - it has crucial implications for the behaviour of the macroeconomy. It implies, for example, that in the short-run, monetary policy changes affect economic activity rather than prices.

It is usually argued that price and wage stickiness is asymmetric, with prices and wages being more flexible when going up than when going down (see, for example, James Tobin in his Presidential Address to the American Economic Society, 1972). Rather than deriving the asymmetry of price and wage stickiness from microeconomics, however, it has been traditional instead to simply assume it, arguing that it arises from social customs, or perhaps from notions of fairness (Kahneman et al., 1986).

In contrast with this traditional approach, modern New Keynesian theories assume that firms' pricing behaviour can be derived from microeconomic first principles. These theories assume the existence of a small "menu" cost associated with changing a price. Faced with this menu cost, it is sometimes optimal for a firm to leave its output price unchanged, when in a frictionless world, the firm would change price. Nominal price stickiness then emerges as a natural consequence of the optimising behaviour of price-setting firms. These theories assume there is nothing special about price falls, as opposed to price rises. Price changes in either direction are instead simply a consequence of firms' microeconomic environment and the shocks they face.

This paper provides empirical evidence to help distinguish between these two competing explanations for *price* stickiness. (The paper does not, however, provide any evidence about *wage* stickiness.) We use a twenty-year sample of Australian industry prices and a forty-year sample of US industry prices to examine two aspects of price stickiness.

First, we use the Australian data to address the question: do firms appear to have any special aversion to price falls? In each period (a quarter or a year) we compare the proportion of industries experiencing a price fall with the proportion experiencing a price rise greater than twice the economy-wide average inflation rate over the period. If there is nothing special about price falls, the proportion of price falls *should not be* systematically smaller than the proportion of price rises greater than twice the inflation rate. Examining both quarterly and annual data, this is indeed the result we find. By this measure, firms do not show any special reluctance to lower their prices.

The paper's main focus, however, is on a second aspect of price stickiness. We examine the implications of a recent New Keynesian model of firm price-setting behaviour developed by Ball and Mankiw (1992a, b) which established novel implications for the relationship between the economy-wide distribution of shocks and the inflation rate.[1]

Our main contribution is to demonstrate the importance of expected inflation for this story. We show that the Ball-Mankiw model has a rich set of implications for the links between expected inflation, the economy-wide distribution of relative-price shocks and actual inflation. When expected inflation is very low, the model implies that a rise in the *dispersion* of shocks has minimal impact on actual inflation while a rise in the *skewness* of shocks is inflationary. When expected inflation is higher, however, a rise in either the dispersion or skewness of shocks is inflationary.

As we show, the empirical evidence from industry price data strongly supports these detailed implications, both at different rates of expected inflation and in two industrial economies, Australia and the United States. This confirms and strengthens the argument that the aggregate implications of price stickiness can be understood in terms of the optimising behaviour of firms with market power responding to the shocks they face. It increases our confidence in our understanding of the microeconomics of firm pricing behaviour and its implications for aggregate inflation.

The paper is organised as follows. The next section discusses our sample of Australian industry price data and examines these data for evidence that firms have an aversion to price falls. Section 3 outlines the Ball-Mankiw model and derives its implications for the relationship between expected inflation, the economy-wide distribution of shocks and the inflation rate. Section 4 uses the Australian industry price data, along with US industry price data used by Ball and Mankiw, to test the implications of the model. It ends with econometric tests of the exogeneity of the key explanatory variable in the industry-price regressions. Section 5 concludes.

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1 In the longer-run, the inflation rate is determined by the stance of domestic monetary policy. In the short-run, however, "supply" or relative-price shocks also have a strong influence.

2. AUSTRALIAN INDUSTRY PRICE DATA

Our data are Australian Bureau of Statistics (ABS) quarterly producer prices for 95 Australian industries weighted by industry output from 1970:1 to 1992:4. With 95 industries, these data are at a quite disaggregated level: examples of the industries are "cement", "footwear", "paints" and "refrigerators". The Data Appendix provides further details.

Figure 1 compares Australian annual industry price inflation (the weighted mean of log industry price changes) and consumer price inflation to show the close correspondence between the two series. Figure 2 shows the distribution of annual industry log price changes for four years in the sample (1972, '74, '85, and '92). In each year, the normal distribution with the same mean and variance as the distribution of industry price changes is also shown.[2] It is clear from the figures that price changes across industries show considerable dispersion. Over the sample, the annual industry price change averages 8% with a standard deviation (averaged across all industries and over time) of 5.5%.

There is also considerable variation in the shape of the distribution of industry price changes. In 1972 and 1985, it is skewed to the right, in 1974 it is skewed to the left, while in 1992, the distribution is roughly symmetric.

Table 1 presents summary statistics for non-overlapping six-monthly and annual industry log price changes over the sample. In each case, the standard deviation and skewness of weighted log price changes across all the industries is presented along with the aggregate producer-price inflation rate (the weighted change in the log of the producer prices).

2.1 Are price falls special?

We can examine these industry-price data for evidence of any aversion by firms to price falls. To do so, we compare the proportion of industries in which the industry price fell with the proportion in which the price rose by more than twice the economy-wide producer price inflation rate (henceforth, the inflation rate).

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[2] The distributions of industry price changes are estimated non-parametrically. For industry i, define Δp^i as the log price change and w_i as the weight of the industry in the producer price index. Then, the density function, $f(\Delta p^*)$ for log price change Δp^* is estimated as $f(\Delta p^*) = \left[2\pi h^2\right]^{-0.5} \sum_{i=1}^{N} w_i \exp\left\{-\left[(\Delta p^i - \Delta p^*)/h\right]^2/2\right\}$, where $h = s_p.\left(\sum_{i=1}^{N} w_i^2\right)^{0.2}$, s_p is the weighted standard deviation of the industry price changes Δp^i, i = 1, …, N and N is the number of industries in the sample (94 or 95). In all cases, the actual distribution of price changes is more peaked than the normal distribution with the same variance.

Consider a simple model in which price-setting firms reset their output price every period. Assume that the *ex ante* distribution of shocks to firms' optimal price is symmetric.[3] *Provided firms have no special aversion to price falls*, the proportion of industries experiencing price falls should then be the same, on average, as the proportion experiencing price rises greater than twice the inflation rate. By contrast, if firms have an aversion to price falls, we should find a smaller proportion of price falls than price rises greater than twice the inflation rate.[4]

Figure 3 shows the proportion of industries with annual price falls and with annual price rises greater than twice the economy-wide inflation rate over the twenty-two years of the sample. There is no obvious evidence from the figure that price falls are less common than price rises greater than twice the inflation rate. Of the twenty-two years in the sample, the proportion of price falls is smaller than the proportion of price rises in eleven years - exactly half the time. There is no evidence here that firms display an aversion to price falls.

This analysis can be repeated using quarterly price changes rather than annual ones. Our sample of 91 quarterly price changes includes 4 quarters during which the average producer price fell. Excluding these quarters, in 46 of the remaining 87 quarters, the proportion of industries experiencing price falls was smaller than the proportion experiencing price rises greater than twice the quarterly inflation rate. 46 out of 87 is close enough to half to conclude that, at least at this level of disaggregation, there appears to be nothing special about price falls (see Appendix 1 for details of the appropriate statistical test).[5]

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3 A symmetric *ex ante* distribution of shocks does not imply a symmetric *ex post* distribution of price changes across the economy in any given period. The data in Table 1 imply that the economy-wide distribution of price changes is often strongly skewed. Averaged over the whole twenty-year sample, however, the distribution of price changes is quite symmetric.

4 Note that, with positive inflation, firms with an aversion to price falls *can engineer a fall in their relative price* by allowing their price to rise more slowly than the general inflation rate.

5 Of course, the test does not distinguish between industries with differentiated and undifferentiated products, which may plausibly exhibit different behaviour. We will briefly return to the issue of firms' aversion to price falls in the next section. Lebow et. al. (1992) examine disaggregated data for both price and wage changes in the US and also conclude that there is little evidence of downward rigidity.

3. THE BALL - MANKIW ANALYSIS

3.1 Description of the Model [6]

We now turn to a more sophisticated model of firms' price formation - the Ball-Mankiw model (1992a,b). The model assumes an economy composed of a large number of price-setting firms that adjust their output prices on a regular basis (say, once a year) but are reluctant to make *special* price adjustments between these regular updates. To make such a special adjustment, firms must pay a small menu cost.

When a firm receives a shock to its optimal output price between one regular price adjustment and the next, its response thus depends on the size of the shock relative to the size of the menu cost. If the shock is small, the firm makes no special adjustment, and instead waits till its next regular price update to re-establish its optimal price. However, if the shock is large, the firm adjusts its output price immediately, because the loss incurred by failing to adjust to a big shock is larger than the menu cost it pays to adjust its price. As a consequence, in the short-run, firms' output prices, and hence the aggregate producer price inflation rate, depends on the economy-wide distribution of *relative price* shocks.

Crucially for the present paper, the effect on inflation of the economy-wide distribution of shocks depends on expected inflation. To see why, consider a firm which expects the (log) aggregate price level to rise steadily through time. With no shocks, this firm's optimal (log) output price also rises steadily as in Figure 4. Assume that the firm sets its output price at time 0 with the intention of re-setting it at time 2. Given this intention, it sets its output price initially at p_o, to minimise the difference between its actual and expected optimal price in the time interval between period-0 and period-2 (see Figure 4).[7]

Now the firm's response to a shock at time 1, between regular price updates, depends on the *sign,* as well as the *size,* of the shock. A negative shock to its optimal price may not elicit a reaction because the firm knows that inflation will do much of the work of raising its optimal nominal price towards its current price p_o (see Figure 4). But after a positive shock of the same size, inflation raises its optimal nominal price *further away from* its current price p_o, and so the firm pays the menu cost and adjusts its price immediately up to p_1^+.

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[6] In this section, we use informal arguments to derive the model's key implications, while a formal summary of it is provided in Appendix 2.

[7] For ease of exposition, we assume the whole time interval between periods 0 and 2 is relevant to the initial pricing decision. In fact, the formal model is set in discrete time (Appendix 2).

Thus, with trend expected inflation, optimal pricing behaviour by firms generates economy-wide price adjustments that are asymmetric. Prices are "stickier" when a firm's optimal price falls than when it rises. Note, however, that it is the presence of trend expected inflation that generates the asymmetric price response. By contrast, when expected inflation is zero, the asymmetry disappears.

A corollary to this observation, which is central to this paper, is that there is a link between the dispersion (standard deviation) of economy-wide relative-price shocks and inflation *when expected inflation is positive but not when it is zero*. With trend expected inflation, few firms make special adjustments to their output prices in periods with a small dispersion of shocks. But in periods with a wide dispersion of shocks, many firms adjust their prices, and most of these adjustments are up. Hence, inflation rises above trend.[8] By contrast, with zero expected inflation, a wide dispersion of shocks still causes many firms to adjust their prices, but as many adjust down as up. Then, a wide dispersion of shocks is not inflationary.

In the next section of the paper, we use industry-price data to test this key implication of the Ball-Mankiw model. Before doing so, however, there are a few issues to be addressed.

Firstly, as we have seen, the model predicts that a high dispersion of shocks is inflationary when expected inflation is positive but not when it is zero. In order to test this prediction with the data, however, it is necessary to know the model's prediction of the effect of dispersion on inflation over a range of rates of expected inflation from zero up to some relevant maximum rate.

Secondly, while the Ball-Mankiw model analyses the reaction of firms to *shocks* to their optimal prices, no data are available on the distribution of underlying shocks. All available data relate to the economy-wide distribution of *industry price changes*. From the perspective of the model, these data reveal only those shocks large enough to have induced a price response by firms. To compare with the data, we therefore derive model predictions for the relationship between the dispersion of industry price changes and inflation as a function of expected inflation.

3.2 Model Simulation Results

The model is sufficiently complex that we cannot derive closed-form expressions for the relationship between the dispersion of shocks and inflation. Instead, we

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[8] Firms are forward-looking and know the distribution of possible shocks, though, *ex ante*, they are unaware whether the period will be one with a low or high economy-wide dispersion of shocks. These assumptions imply that inflation falls below trend in periods with a low dispersion of shocks and rises above trend when the dispersion of shocks is high. By assumption, deviations from trend inflation do not change future expected inflation (that is, shocks to the aggregate price level are permanent.)

present results derived from simulations of the model. These results are derived assuming all firms in an industry are identical so that shocks to the firms' optimal price (henceforth, optimal price shocks) are industry-specific. In any time-period, we assume the economy-wide distribution of optimal price shocks has a normal distribution $N(0, SDS^2)$ with the standard deviation of shocks, *SDS*, taking a (randomly chosen) value in the range $\underline{S} \leq SDS \leq \overline{S}$. A period with a low economy-wide dispersion of shocks is one with $SDS \approx \underline{S}$, while a period with a high dispersion of shocks has $SDS \approx \overline{S}$.

We choose bounds for the dispersion of shocks, $\underline{S}, \overline{S}$, to match features of the Australian data and assume all firms face identical menu costs. We also assume all firms face an identical distribution of possible shocks but, *ex ante*, are unaware whether the period will be one with a low or high economy-wide dispersion of shocks.

For given expected inflation, we choose a series of values of *SDS* in the range $\underline{S} \leq SDS \leq \overline{S}$ and, for each value of *SDS*, derive the inflation rate predicted by the model, Δp, and the value for *SDP*, the economy-wide standard deviation of industry price changes, generated by the model. For given expected inflation, these model simulations are usefully summarised by deriving coefficient estimates from two OLS regressions:[9]

$$\begin{aligned} \Delta p &= a + bSDS + u, \\ \Delta p &= g + dSDP + v. \end{aligned} \tag{1}$$

Figure 5 reports the results which are consistent with the intuitive arguments presented above. When expected inflation is zero, the model implies *no relationship* between the dispersion of shocks, *SDS*, and inflation, Δp, while with positive expected inflation, there is a positive relationship. Note also that as expected inflation rises, the model relationship between the dispersion of shocks and actual inflation becomes progressively stronger. Furthermore, as is clear from Figure 5, the same qualitative picture emerges when the regression is run with the standard deviation of industry price changes, *SDP*, replacing the standard deviation of shocks, *SDS*.[10]

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9 The period of the model is assumed to be six months. For given expected inflation, model results are derived for ten values of *SDS* in the range $\underline{S} \leq SDS \leq \overline{S}$, which leads to ten different values for *SDP* and for Δp. The regression results are derived from these ten simulated outcomes. Both regressions provide very good empirical descriptions of inflation in the model, with $R^2 > 0.94$ for all values of expected inflation up to an annualised rate of 15% p.a. See Appendix 2 for further technical details.

10 How large is the predicted effect on inflation? With expected inflation of zero, of course, any change in the economy-wide dispersion of shocks has no impact on actual inflation. With

Before turning to empirical tests with industry price data, we address the implications of skewness in the distribution of underlying shocks. As Ball and Mankiw (1992b) stress, their model makes strong predictions about the impact on inflation of a skew distribution of underlying shocks. Again, this can be understood from a simple informal argument. If the economy-wide distribution of relative price shocks is positively skewed, there are big rises in the optimal price for a few industries offset by small falls in the optimal prices for the rest of the economy. Firms facing the big positive shocks adjust their prices up immediately, while the others make no special adjustment. It follows that a positively (negatively) skewed distribution of relative price shocks is inflationary (disinflationary) in the short-run. Furthermore, this argument clearly applies whatever the rate of expected inflation.

For our purposes, it is important to know how the presence of skewness in the distribution of shocks affects the links between dispersion, expected inflation and actual inflation. To address this issue, we again present results from a model simulation.[11]

We make the same assumptions as before, with the exception that shocks are no longer normally distributed. Instead, we assume the economy-wide distribution of shocks is a sum of two normal distributions with different means and variances (suggested by the Australian data on industry price changes which often resemble the sum of two normal distributions, see Figure 2).[12] Allowing the mean and/or variance of one of the two normal distributions to vary, implies that the dispersion and/or skewness of the underlying shocks also varies.

Parameters for the distribution of shocks are again chosen to match features of the Australian data, and the model results are now summarised by generating coefficient estimates from these two OLS regressions:

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expected inflation of 3% p.a., a two standard deviation rise in the dispersion of shocks leads to a rise in actual inflation of 0.5% p.a. (measured at an annualised rate) while with expected inflation of 8% p.a., the rise in actual inflation is a much larger 1.2% p.a. (Recall that the model is calibrated to match actual Australian data.) Thus, with expected inflation of 8% p.a., a typical rise in the economy-wide dispersion of shocks from one six-month period to the next is predicted to lead to a substantial, albeit temporary, rise in inflation.

[11] Ball and Mankiw (1992b) also present model simulation results for the relationship between dispersion and skewness of industry price changes and inflation, but their results are restricted to the case when expected inflation is zero.

[12] The US distribution of price changes often looks the same - see Figure 3 in Ball and Mankiw (1992b). While the distribution of price changes is not the same as the distribution of shocks, the former at least provides a guide for the latter.

$$\Delta p = a + bSDS + gSKS + u,$$
$$\Delta p = a + b\,SDP + c\,SKP + v, \tag{2}$$

where Δp is again the model-generated aggregate inflation rate, *SKS* is the skewness of the economy-wide distribution of shocks and *SKP* is the skewness of the distribution of industry price changes.[13]

Results are shown in Figures 6 and 7. As the informal argument above should lead one to expect, the model implies that a rise in the skewness of shocks, *SKS*, is always inflationary (Figure 6). Furthermore, the effect of the skewness of shocks on inflation is largely independent of the rate of expected inflation. Interestingly, the effect of expected inflation on the link between the *dispersion* of shocks, *SDS*, and the inflation rate is the same (qualitatively) as its effect in the earlier simulation when skewness played no role. That is, a rise in the rate of expected inflation progressively increases the strength of the link between dispersion and actual inflation whether the underlying shocks are symmetric or not.

Again, the story is fairly similar when the moments of industry price changes, *SDP* and *SKP*, replace the moments of shocks, *SDS* and *SKS*, in the inflation regression (Figure 7). The coefficient on *SKP* is relatively insensitive to expected inflation, while the coefficient on *SDP* rises strongly with expected inflation (at least up to expected inflation of about 6% per annum).[14]

To summarise, the Ball-Mankiw model has a rich set of implications for the links between expected inflation, the economy-wide distribution of relative-price shocks and actual inflation. When expected inflation is very low, a rise in the dispersion of shocks has minimal impact on actual inflation while a rise in the skewness of shocks is inflationary. When expected inflation is higher, a rise in either dispersion or skewness is inflationary. Furthermore, these statements remain true when the (economy-wide) moments of industry price changes replace the moments of the underlying shocks.

Before turning to empirical tests, we briefly touch on the relevance of the Ball-Mankiw model for the statistical test in the earlier section: Are price falls special? As we have discussed, the Ball-Mankiw model predicts that in the presence of expected trend inflation, prices are more sticky when falling than when rising. It follows that, with expected trend inflation, the proportion of price falls *should be*

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13 As before, both regressions provide very good empirical descriptions of inflation in the model, with $R^2 > 0.9$ for all values of expected inflation up to 15% p.a.

14 We also established that the moments of industry price changes are well explained by the respective moments of underlying shocks. For the regression, $SDP = a + bSDS + u$, $R^2 > 0.96$ for all rates of expected inflation up to 15% p.a., while for the regression, $SKP = a + bSKS + u$, $R^2 > 0.88$.

less than the proportion of price rises greater than twice the inflation rate. However, if the economy-wide distribution of price shocks is often negatively skewed *ex post*, this argument is not very critical because in these periods, the Ball-Mankiw model predicts that the proportion of price falls will be higher than the proportion of price rises greater than twice the inflation rate. The fact that the statistical tests reported in the earlier section accept the hypothesis that the proportions are equal is therefore corroborative evidence that the underlying shocks are often significantly negatively skewed.

4. TESTING THE BALL-MANKIW MODEL WITH INDUSTRY PRICE DATA

We now turn to formal regression analysis of the industry price data to test the empirical implications of the Ball-Mankiw model. As mentioned in Appendix 2, microeconomic evidence on the frequency of price adjustments (Blinder, 1991; Cecchetti, 1986) suggests a period of six-months as appropriate for comparison with the model. We therefore present results using six-month price changes. We also present results with annual price changes to allow direct comparison with Ball and Mankiw's results for the US and to test the robustness of our conclusions.

In our regressions, the dependent variable is either the aggregate producer-price inflation rate or its change. In each case, explanatory variables are moments (standard deviation, skewness) of the economy-wide distribution of industry-price changes. Lags of the dependent variable are included in the regression to capture persistence.

Tables 2-5 compare annual results for the two twenty-year US sub-samples and for the Australian sample.[15] Over each roughly twenty-year sample, we assume that the average inflation rate is a good proxy for the average expected inflation rate. Then, the three samples with their different average inflation rates (1.3% p.a. in the US, 1949-69, 5.7% in the US, 1970-89, and 8.0% p.a. in Australia, 1972-92) allow us to test the model's predictions of the relationship between inflation and the moments of industry price changes as expected inflation changes.[16]

The Tables report results using both inflation and its change as regressors. Tables 4 and 5 include (Hodrick-Prescott filtered) unemployment to capture the effect of the business cycle on inflation. The 'change in inflation' regressions (Tables 3 and 5) establish the robustness of the results and are also included because, in

[15] The US data are the weighted results from Table II of Ball and Mankiw (1992b).

[16] These tests implicitly assume that the distribution of shocks in the two countries was similar - which is supported by a comparison of annual moments of industry price changes in the two economies (Table 1 and Ball and Mankiw, 1992b, Table II).

many cases, they eliminate serial correlation problems that are present in the 'inflation' regressions.

There are clear patterns in the regressions as the average rate of inflation rises. To begin, consider regressions including the standard deviation of industry price changes but not the skewness. At the lowest level of average inflation (1.3% p.a. in the US, 1949-69), the standard deviation of price changes is insignificant (and, in fact, slightly negative) in all the Tables. Moving down each Table, the average level of inflation rises and the estimated coefficient on the standard deviation of price changes also rises, becoming increasingly significant and, in most cases, adding progressively more explanatory power to the equations. As we have seen in Figure 5, the first model simulation predicts this rise in the coefficient on the standard deviation as expected inflation rises.

The skewness of industry price changes apparent from Table 1 and Figure 2 suggests that underlying shocks often have a skewed distribution. The logic of the Ball-Mankiw model then suggests that adding the skewness of price changes to the regressions should significantly improve their explanatory power.

The results are again very encouraging. Adding skewness to the regressions in Tables 2-5 always improves the regression $\bar{R}^2$. The coefficient estimate on the skewness variable is always positive, usually highly significant, and shows no obvious pattern as average inflation changes. By contrast, there is a clear pattern in the estimated coefficient on the standard deviation variable in these regressions. At the lowest average inflation rate, this coefficient is of indeterminant sign and always insignificant. However, as average inflation rises, the coefficient becomes highly significant and positive. These results are strikingly similar to those from the model simulation that allows for a skewed distribution of shocks (see Figure 7).[17]

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[17] Ball and Mankiw (1992b) *do not* point out that their model implies changing coefficients in these regressions as expected inflation changes. On the contrary, in their Table VII, they show regressions in which the estimated coefficients are relatively stable across the sub-periods 1949-69 and 1970-89. The relevant regressions in their Table include standard deviation, skewness and the product of standard deviation and skewness as regressors. Using our "double-normal-distribution" simulation and associated parameters, this regression *does not* have stable coefficients when expected inflation changes. The model coefficients on the relevant variables change by between a factor of two and four when expected inflation rises from its average rate in 1949-69 (1.3% p.a.) to its average rate in 1970-89 (5.7% p.a.)

Table 6 shows Australian six-monthly results which are similar to the annual results. The coefficients on standard deviation and skewness are always positive as expected, with the former always highly significant.[18]

We now turn to an alternative regression specification to test the model prediction that the coefficient on the standard deviation of industry price changes is strongly dependent on expected inflation. The results in Figures 5 and 7 suggest that, at least for moderate rates of expected inflation, the product of expected inflation and the standard deviation of industry price changes (henceforth, the product variable) should provide a better explanation for inflation than the standard deviation on its own. Using the past year's inflation as a proxy for expected inflation, we use six-monthly data to examine this hypothesis in Table 7.

The results again support the model predictions. The product variable provides better explanatory power than the standard deviation variable, both with and without skewness in the regression. Furthermore, in the final regression in Table 7, the product variable dominates the standard deviation variable when both are included in the regression.[19]

Ball and Mankiw (1992b) argue that the inflation-skewness relationship is stronger than the inflation-dispersion relationship in the post WWII US. Our results suggest that the relative strength of these two relationships depends critically on expected inflation. For expected inflation below about 4 to 5 per cent per annum, the inflation-skewness relationship is relatively stronger. For higher expected inflation, however, the inflation-dispersion relationship is relatively stronger.[20]

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[18] Note, however, that while the qualitative agreement between the model and the empirical results is impressive, the quantitative agreement is less so. We compare six-monthly results since the model parameters are chosen to match features of the six-month industry price moments. Including only standard deviation (SDP) in the regression, the first model simulation predicts a coefficient of 0.16 when expected inflation is 8% p.a., while the regressions in Table 6 give a coefficient estimate of about 0.35. Including both standard deviation and skewness (SKP) in the regression, the second model simulation predicts coefficients of 0.019 and 0.0018 respectively when expected inflation is 8% p.a., while Table 6 gives coefficient estimates of about 0.3 and 0.0008.

[19] Figure 7 predicts a non-linear relationship between expected inflation and the coefficient on the standard deviation of industry price changes. To test this prediction, we included the product of standard deviation and the *square* of the past year's inflation in the final regression in Table 7. The coefficient on this variable was negative, as expected, but insignificant.

[20] This conclusion (and the one in the next paragraph of the text) is based on the penultimate regression in Table 7 and on the sample standard deviations of six-monthly moments of Australian industry price changes from Table 1. When past annual inflation is 4.5%, a one standard deviation shock to the standard deviation of industry price changes has the same

The Ball-Mankiw observation that the skewness-inflation relationship is relatively stronger in the post-WWII US is then seen to be a consequence of the low average rate of expected inflation in the US over this time. By contrast, over our twenty year sample of Australian data, inflation (and, by inference, expected inflation) averaged 8 per cent per annum. At this rate of expected inflation, the dispersion-inflation relationship is almost twice as strong, empirically, as the skewness-inflation relationship.

To summarise, the empirical results support the detailed predictions of the Ball-Mankiw model. When average (expected) inflation is very low, a rise in the dispersion of shocks (and of price changes) has minimal impact on actual inflation while a rise in the skewness of shocks is inflationary. By contrast, when average (expected) inflation is higher, a rise in either the dispersion or skewness of shocks is inflationary.

4.1 Tests for exogeneity based on the terms of trade

As we have seen, the Ball-Mankiw model establishes a causal link from shocks to firms' optimal relative prices to their pricing behaviour and hence to aggregate inflation. There are, however, several plausible ways in which aggregate inflation or shocks to inflation may *cause* relative price variability rather than being a consequence of it (see, e.g., Sheshinski and Weiss, 1977 and Fischer, 1981). If so, there is an endogeneity bias in the regressions reported above because the regression error terms are correlated with at least one of the explanatory variables.

This sub-section examines this problem. It reports Hausman (1978) exogeneity tests for the standard deviation of industry price change variable in three of the Australian regressions already discussed. To conduct these tests, we need an instrument correlated with this variable but uncorrelated with the error term. Our choice of instrument is suggested by the nature of the Australian economy. Australia is small in world markets for almost all its traded-goods, implying that its terms of trade are exogenous to the Australian economy. Furthermore, as a commodity-exporting and manufactures-importing economy, Australia's terms of trade are among the most volatile in the OECD (Gruen and Shuetrim, 1994).

Since a terms of trade shock is a shock to the relative price of exports to imports and since both exports and imports form a substantial part of the Australian economy (with ratios to GDP of about 15% in the 1970s and early 1980s, rising to nearly 20% in the early 1990s) changes in the relative price of exports to imports should have a significant impact on relative prices in the wider economy.

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predicted effect on inflation as a one standard deviation shock to the skewness of industry price changes.

Table 8 examines the impact of terms of trade changes on the standard deviation of industry price changes. The Table shows regressions both before and after the float of the Australian dollar and examines both six-monthly and annual industry price changes.[21] While terms of trade changes *do not explain* the standard deviation of industry price changes, the absolute value of terms of trade changes is a highly significant explanator of the standard deviation of industry price changes.[22] Thus, *both favourable and adverse* terms of trade shocks are associated with a high dispersion of industry price changes. By contrast, when the terms of trade are relatively stable, the dispersion of industry price changes across the economy tends to be low.

Given the earlier analysis in this paper, this result implies that both favourable and adverse terms of trade shocks are inflationary when expected inflation is high but not when it is low. In a future paper, we intend to examine these implications in more detail.

For the purpose of the current paper, however, the absolute change in the terms of trade is a natural instrument for the standard deviation of industry price changes. As well as being highly correlated with the standard deviation variable, this instrument should be uncorrelated with the regression error term.[23]

Table 9 reports IV and OLS regressions for three inflation regressions - chosen because they are representative and because the OLS regression errors show no signs of serial correlation. In each case, under the null hypothesis that the standard deviation of industry price changes is exogenous, the coefficient estimates from the IV and OLS regressions should not be significantly different.

While the results are strongly suggestive that the standard deviation variable is exogenous, they are not decisive. The formal hypothesis that there is no difference

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[21] Since the sub-samples are short, we use overlapping data. For the six-monthly (annual) data, the post-float results start at 1984:3 (1985:1) to include only those price changes with a starting date after the December 1983 float of the Australian dollar.

[22] Chow tests suggest no evidence of a change in the coefficients between the pre and post-float regressions for either six-monthly or annual price changes (results not shown).

[23] The change in the terms of trade (rather than its absolute value) could be correlated with the error term in the regressions because it may affect inflation independently of its effect on the distribution of industry price changes. Possible channels for this link are the effect of a terms of trade change on domestic income and the nominal exchange rate, and via these, on inflation. However, since rises and falls in the terms of trade should have *opposite effects* on both income and the exchange rate, the absolute value of the change in the terms of trade should not be correlated with them and hence should not be endogenous to the regressions. As a further check, we repeated the analysis with regressions including H-P filtered unemployment (to control for excess domestic demand) and the change in the nominal trade-weighted exchange rate (TWI). Our conclusions are robust to these changes.

between the coefficients is always easily accepted (see the p-values in the final column in the Table). However, in each case, instrumenting the standard deviation variable increases the estimated standard error considerably. As a consequence, although the coefficient on the standard deviation variable (or the product variable) in the IV regressions is always of the expected sign, it is not very significant.

5. CONCLUSIONS

At the outset, we contrasted two explanations for the observation that prices are "stickier" when going down than when going up. The traditional explanation is that this asymmetry arises from social customs or some special aversion by firms to allowing their output prices to fall. This traditional view implies that asymmetric price stickiness is not amenable to microeconomic analysis. The alternative view, associated with the New Keynesian literature, starts with the observation that changing price is not costless. Once this is recognised, asymmetric price stickiness follows from the optimising response of price-setting firms to their microeconomic environment and the shocks they face, rather than from an aversion to reducing their prices.

We have two strands of evidence supporting the latter, New Keynesian, analysis of price stickiness. The first strand of evidence is very simple: our industry price data do not reveal any aggregate evidence that firms have a special aversion to price falls.

The second strand of evidence is more involved. It requires detailed analysis of the Ball-Mankiw model of firm's price-setting behaviour. Ball and Mankiw established novel implications for the relationship between the economy-wide distribution of price changes and inflation in the short-run. Our main contribution is to demonstrate the importance of expected inflation for this story. We derive the detailed implications of the Ball-Mankiw model for the relationship between expected inflation, the economy-wide distribution of industry price changes and actual inflation and show that both US and Australian industry-price data strongly support these implications.

While the correlation between relative price dispersion and inflation has been well-known and widely-analysed (see e.g., Fischer 1981) the correlation between inflation and the *skewness* of price changes was an empirical curiosity in search of an explanation. Ball and Mankiw (1992b) provided an explanation for the correlation, and established that the relationship between skewness and inflation is stronger, empirically, than the dispersion-inflation relationship in the post-WWII United States.

We establish a further implication of the Ball-Mankiw model: that the relative strength of the skewness-inflation and dispersion-inflation relationships depends critically on expected inflation. When expected inflation is low, the skewness-inflation relationship is the stronger of the two. As expected inflation rises, however, the dispersion-inflation relationship becomes increasingly important. The skewness-inflation relationship is estimated to be the stronger for expected inflation below about 4 to 5 per cent per annum, while the dispersion-inflation relationship is the stronger for higher rates of expected inflation.

The Ball and Mankiw result that the skewness-inflation relationship is the stronger in the post-WWII United States is then a consequence of the low average rate of expected inflation in the United States over this time. By contrast, over our twenty year sample of Australian data, inflation (and, by inference, expected inflation) averaged 8 per cent per annum. At this rate of expected inflation, the relationship between dispersion and inflation is stronger empirically than the skewness-inflation relationship.

As we have seen, the empirical evidence from industry price data supports the detailed predictions of the model, both at different rates of expected inflation and in two different industrial economies. This confirms and strengthens the argument that the aggregate implications of price stickiness can be understood in terms of the optimising behaviour of firms with market power responding to the shocks they face. It increases our confidence in our understanding of the microeconomics of firm pricing behaviour and its implications for aggregate inflation.

To conclude, we discuss the policy relevance of the analysis. As we have seen, the inflationary impact of relative price shocks depends strongly on expected inflation. When expected inflation is high, a rise in the economy-wide dispersion of shocks is inflationary in the short-run. By contrast, when expected inflation is low, a rise in the dispersion of shocks has minimal impact on inflation. Economy-wide relative price shocks, like terms of trade shocks, are an unavoidable feature of the economic landscape. Their disruptive effect on inflation is minimal, however, when average inflation, and therefore average expected inflation, is kept low.

DATA APPENDIX

Producer price data are unpublished producer prices from the Wholesale Price Section, the Australian Bureau of Statistics. 94 industry categories were used (the transport services category was added in 1987 making 95) from a possible 109 industry categories. The 95 industry categories are listed at the end of this Appendix. The 14 remaining categories were excluded as they were not strictly price series but were implicit price deflators derived for the categories concerned.

The prices are weighted using nominal GDP(I) for each industry, available for the financial years 74/75, 78/79, 80/81, 82/83, 86/87 and 90/91. Weights are linearly interpolated for the intervening time periods.

The CPI for Australia is the Medibank and Medicare adjusted series obtained from internal Bank sources. Australian terms of trade data are terms of trade for goods and services from the ABS National Accounts, Catalogue Number 5206.0. Australian nominal trade-weighted exchange rate (TWI) is quarterly average data. Unemployment rate data for Australia are from *The Labour Force: Australia,* ABS Catalogue Number 6203.0.

All data series are quarterly. Annual (six-monthly) data for these series have been calculated by taking the average of the four (two) relevant quarters' data.

Annual unemployment rate data for the United States are from *Employment and Earnings*, the United States Department of Labour, Bureau of Labour Force Statistics.

The 95 industry categories are:

advertising
agricultural machinery
agriculture nec
agricultural services
air transport
aircraft
alcohol nec
basic iron, steel
basic non-ferrous
beer, malt
bread, cakes
cement
cereals
chemical fertilisers
chemicals, basic
chemicals nec
clay products
clothing
coal, oil, gas
communication
confectionary
concrete
concrete products
construction machinery
construction nec
containers
cosmetics
cotton ginning
cotton fabrics
electrical nec
electricity
electronic
ferrous
fishing
flour, cereal
food products nec
footwear
forestry
fruit, veg
furniture
gas
glass
knitting
leather products
machinery nec
man-made fibres
manufacturing nec
margarine, fats nec
meat cattle
meat products
mechanical repairs
metal products nec
milk cattle, pigs
milk products
minerals nec
mining services
motor vehicles
non ferrous
non metallic nec
paints
paper products nec
petroleum products
photographic
pharmaceutical
plastic products
poultry
publishing
pulp, paper
railway
railway transport
refrigerators
repairs nec
residential building
retail trade
road transport
rubber products
sawmill products
sheep
sheet metal
ships, boats
soap
soft drinks
stationery
structural metal
textiles
textiles
textiles nec
tobacco
transport services
water
water transport
wholesale trade
wood boards
wood products nec
woollen fabrics

Note: nec denotes not elsewhere classified

APPENDIX 1: STATISTICAL TEST: ARE PRICE FALLS SPECIAL?

Define Δp_t as the economy-wide average change in producer prices in period *t*. Then define z_t= 1 (-1) if the proportion of industries with price falls in period *t* is lower (higher) than the proportion with price rises greater than $2\Delta p_t$. Finally, define $Z = (z_1 + \ldots + z_T) / T$. Under the null hypothesis that price falls are as likely as price rises greater than $2\Delta p_t$, and that price changes in each period are independent, it is straightforward to show that $E(Z) = 0$ and $Var(Z) = 1/T$. It follows from the central limit theorem that $Z\sqrt{T}$ is (approximately) a standard normal variable. For our sample of quarterly price changes, $T = 87$, $Z = 5/87$ and hence $Z\sqrt{T} \approx 0.54$ which is insignificantly different from zero. Hence, we accept the null hypothesis.

APPENDIX 2: THE BALL-MANKIW MODEL

The model is set in discrete time in an economy consisting of a continuum of price-setting firms. Half the firms, "odd firms", always adjust their output price in odd periods ($t = 1,3,...$) and half, "even firms", always adjust in even periods ($t = 0,2,...$). The aggregate price level, p_t (all prices in logs) rises at an exogenously specified rate π and hence $p_t = \pi t$. All firms expect this rising aggregate price level.

Consider an even firm, and let *x* be the output price the firm sets in period 0. This price *x* will apply, at most, for periods 0 and 1 since the firm always resets its price in even periods. The model has three key assumptions.

Assumption 1: The firm can adjust its output price in period 1, but only by paying a menu cost, C.
Assumption 2: The firm's optimal *relative* price in period *t*, Θ_t, follows a random walk, $\Theta_t = \Theta_{t-1} + q_t$, where q_t are serially-uncorrelated mean-zero shocks with distribution function, $F(q_t)$.
Assumption 3: Any difference between the firm's actual price and its optimal price entails a cost equal to the square of this difference with the cost over two periods being the undiscounted sum of costs incurred in each period.

With the aggregate price level rising at rate π, the firm's optimal nominal price in period *t* is $\pi t + \Theta_t$. As a normalisation, set $\Theta_0 = 0$, so the firm's optimal nominal price is zero in period 0, and $\pi + \Theta_1 \equiv \pi + q$ in period 1 (dropping the subscript 1 when it causes no confusion). With a period 1 optimal price $\pi + q$ and an initial price *x*, the cost of *not adjusting* price in period 1 is $(\pi + q - x)^2$. Thus, the firm will not adjust in period 1 if $(\pi + q - x)^2 < C$; that is if

$$q \in [\underline{q}, \bar{q}],$$

where
$$\underline{q} = x - \pi - \sqrt{C}; \qquad (3)$$
$$\bar{q} = x - \pi + \sqrt{C}.$$

Note a key implication of equation (3). With positive expected inflation, π, and provided $x < \pi$, the inaction band $[\underline{q}, \bar{q}]$ is asymmetric. The firm adjusts its output price up in response to smaller positive shocks than it adjusts down in response to negative ones. Note also, that when $q \notin [\underline{q}, \bar{q}]$, the firm pays the menu cost, C, and adjusts it's price to the period 1 optimal price, $\pi + q$, simply because this price will only be in effect for this single period. In period 0, the firm minimises:

$$Cost = x^2 + \int_{q=\underline{q}}^{\bar{q}} (\pi + q - x)^2 \, dF(q) + [1 - (F(\bar{q}) - F(\underline{q}))]C. \qquad (4)$$

The first term is the firm's loss in period 0 when the optimal price is zero while the actual price is *x*. The second and third terms are the expected loss in period 1. The loss is $(\pi + q - x)^2$ when the firm does not adjust it's output price in period 1 while the loss is equal to the menu cost, C, when it does adjust. The first-order condition for minimising the cost with respect to *x* gives

$$x = \frac{1}{1 + F(\bar{q}) - F(\underline{q})} \left\{ \int_{q=\underline{q}}^{\bar{q}} (\pi + q) \, dF(q) \right\}. \qquad (5)$$

Equation (5) has a simple interpretation. The price *x* is the weighted average of the firm's optimal price in period 0 and its expected optimal price in period 1 conditional on the initial price remaining in effect. The weights are the probabilities that *x* is in effect in the two periods, which are 1 for period 0 and $F(\bar{q}) - F(\underline{q})$ for period 1. Together, equations (3) and (5) define *x*, $\underline{q}$ and $\bar{q}$.

Inflation and the sectoral dispersion of shocks

We now derive the model relationship between inflation and the economy-wide dispersion of relative price shocks. By assumption, all firms in an industry have the same optimal price and, *ex ante*, all industries face the same distribution of possible shocks. We calculate the inflation rate between periods 0 and 1, and to do so, must specify the economy-wide distribution of shocks in several periods including period 1.[24] For periods $t \neq 1$, we assume a general distribution of shocks, while the period 1 distribution is a particular realisation from this general distribution.

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[24] Odd-firm pricing behaviour in periods –1, 0 and 1, and even-firm pricing behaviour in periods 0 and 1 all contribute to the inflation rate between periods 0 and 1.

For periods $t \neq 1$, relative price shocks, q_t, are drawn from a normal density $N(0, s^2)$ with the standard deviation, s, drawn from a uniform density $h(s)$ with $\underline{S} \leq s \leq \bar{S}$. The distribution function for q_t, $t \neq 1$ is then given by

$$F(q_t) = \int_{s=\underline{S}}^{\bar{S}} F(q_t, s)\, h(s)\, ds\,, \tag{6}$$

where $\Phi(q_t, s)$ is the distribution function for the normal density $N(0, s^2)$.

Period 1 industry-specific relative price shocks, q_1, are distributed $N(0, SDS^2)$ where $s = SDS$ (standard deviation of shocks) is a particular draw from the density $h(s)$. Period 1 has a large dispersion of shocks when $SDS \approx \bar{S}$ or a small dispersion of shocks when $SDS \approx \underline{S}$.

All firms face the same menu cost, C, and so their price-setting can be derived from the analysis leading to equations (3) to (5).[25] For given period 1 relative-price dispersion (given SDS) the inflation rate between period 0 and period 1, $\Delta p(SDS)$, is given by

$$\begin{aligned} Dp(SDS) = 0.5 \Big[& \int_{q_0=\underline{q}}^{\bar{q}} \int_{q_1=-\infty}^{\infty} (2p + q_0 + q_1)\, dF(q_1, SDS)\, dF(q_0) \\ & + (1 - F(\bar{q}) + F(\underline{q})) \int_{q_1=-\infty}^{\infty} (x + p + q_1)\, dF(q_1, SDS) \\ & + \int_{q_1=-\infty}^{\underline{q}} (p + q_1 - x)\, dF(q_1, SDS) + \int_{q_1=\bar{q}}^{\infty} (p + q_1 - x)\, dF(q_1, SDS) \Big]. \end{aligned} \tag{7}$$

The first term in this equation reflects odd firms that do not adjust their period -1 output price in period 0 while the second term reflects those that do. Even firms that adjust their period 0 output price down in period 1 are captured by the third term while those that adjust it up give the fourth term. Of course, firms which do not adjust their output price from period 0 to period 1 do not contribute to inflation between the two periods, $\Delta p(SDS)$.

To derive the dispersion of industry price changes, SDP, we use the terms in equation (7) for the behaviour of the four groups of firms that change their output

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[25] The dispersion of period 1 relative-price shocks, SDS, is revealed in period 1. Thus, when even firms set their output price in period 0, they use the unconditional distribution function for q_1, $F(q_1)$ where $F(.)$ is given by equation (**Error! Bookmark not defined.**). Of course, this is also the distribution function for next period shocks used by odd firms when they set their output price in period −1 or in period 1. Expected inflation for all firms is p, though, of course, actual inflation in period 1 will depend on the distribution of shocks.

price in period 1, as well as for the aggregate price change. Then, defining the output price of firms in industry i in period t as p_t^i and the aggregate price level as p_t, the standard deviation of industry price changes, SDP, is given by

$$SDP^2 = E(\Delta p_1^i)^2 - (\Delta p_1)^2, \tag{8}$$

where the expectation is over all industries i.

Following Ball and Mankiw, we assume that the menu cost for all firms, C, is $C = (0.125)^2$ which implies that firms tolerate a 12.5% deviation between their actual and optimal prices before making a special adjustment. We also assume prices are regularly adjusted once a year, so that the period of the model is six months. These assumptions are based on microeconomic evidence on the frequency of price adjustments (Blinder, 1991; Cecchetti, 1986).[26]

Bounds on SDS ($\underline{S} = 0.01$, $\overline{S} = 0.108$) are chosen to generate a standard deviation of the dispersion of industry price changes, SDP, that matches the Australian data.[27] For given expected inflation, π, the model is used to generate actual inflation, Δp, and the inter-industry dispersion of price changes, SDP, as the inter-industry dispersion of shocks, SDS, varies uniformly over its range $\underline{S} \le SDS \le \overline{S}$. Then the two OLS regressions in the text, equation (1), are estimated.

A Skew Distribution of Underlying Shocks

As before, we generate the inflation rate between periods 0 and 1 and the distribution of shocks for periods $t \neq 1$ is a general distribution while the period 1 distribution is a particular realisation from this general distribution. We begin with a distribution function

$$G(q_t) = \alpha\,\Phi(q_t; \mu_1, \sigma_1^2) + (1-\alpha)\Phi(q_t; \mu_2, \sigma_2^2), \tag{9}$$

---

[26] Blinder's survey of US firms with annual sales over \$10 million reveals that 24.5% adjust prices more than twice a year, 20.3% adjust between once and twice and 55.1% adjust once or less than once a year. On average, these firms change their output price 3 to 4 months after a significant change in demand or cost conditions.

[27] Aggregate industry price inflation over our 1970-92 sample averages 8%p.a., while the dispersion across industries of (non-overlapping) six-monthly log price changes averages $SDP = 0.038$ and itself has a standard deviation (across different time periods) of 0.018. For the model, the standard deviation of the dispersion of price changes, SDP, is also 0.018 when $\pi = 0.04$ per period (8% p.a.) and SDS is distributed uniformly over the range $0.01 = \underline{S} \le SDS \le \overline{S} = 0.108$.

where $\Phi(q_t;\mu_i,\sigma_i^2),\ i=1,2$ are normal distribution functions with means and variances as shown and α is the probability weight of the first normal distribution.[28] Since $G(q_t)$ is a distribution of relative price shocks, q_t must have mean zero, and hence

$$\mu_2 = -\alpha\mu_1/(1-\alpha). \tag{10}$$

The standard deviation of the distribution of shocks, SDS, and the skewness of the distribution of shocks, SKS, are given by

$$SDS^2 = \alpha(\sigma_1^2+\mu_1^2)+(1-\alpha)(\sigma_2^2+\mu_2^2), \tag{11}$$

and
$$SKS = \left[\alpha(3\mu_1\sigma_1^2+\mu_1^3)+(1-\alpha)(3\mu_2\sigma_2^2+\mu_2^3)\right]/SDS^3. \tag{12}$$

We impose values for α and σ_2 to match moments of the distribution of Australian industry price changes (see later). With these imposed values and with equation (10) determining μ_2, the distribution function, $G(q_t)$, is a function of the moments of the first normal distribution, $G(q_t)\equiv G(q_t;\mu_1,\sigma_1)$. We assume μ_1 and σ_1 are independent and drawn from a uniform density $c(\mu_1,\sigma_1)$ with $-\mu\le\mu_1\le\mu$ and $\underline{\Sigma}\le\sigma_1\le\overline{\Sigma}$. The chosen parameter values imply that when $\mu_1<0$ (and hence $\mu_2>0$) the distribution is positively skewed, when $\mu_1>0$ it is negatively skewed, while when $\mu_1=0$, the distribution is symmetric. The distribution function for $q_t,\ t\neq 1$ is then

$$F(q_t)=\int_{\sigma_1=\underline{\Sigma}}^{\overline{\Sigma}}\int_{\mu_1=-\mu}^{\mu} G(q_t;\mu_1,\sigma_1)\,c(\mu_1,\sigma_1)\,d\mu_1\,d\sigma_1. \tag{13}$$

Period 1 shocks, q_1, have a distribution function $G(q_1;\mu,\sigma)$ where $\mu_1=\mu$ and $\sigma_1=\sigma$ represent a particular draw from the density $c(\mu_1,\sigma_1)$. Then, the dispersion and skewness of the distribution of period 1 shocks, *SDS* and *SKS*, are given by equations (11) and (12) with $\mu_1=\mu$ and $\sigma_1=\sigma$. The distribution of q_1 has a low (high) dispersion of inter-industry shocks when the derived value of *SDS* is small (large). Likewise, the derived value of *SKS* determines whether the distribution of period 1 shocks is symmetric, negatively skewed or positively skewed. Varying μ and σ independently in the parameter space defined by

[28] An alternative to this distribution is the skew-normal distribution analysed by Ball and Mankiw (1992b). However, the skew-normal distribution only permits a fairly narrow range of possible skewness (from -0.995 to 0.995) which seems too small to match the range of skewness in either the Australian or US industry-price data. When calibrated to match the Australian data, the distribution generated below has a standard deviation of the skewness of shocks equal to 3.6.

$-\bar{\mu} \le \mu \le \bar{\mu}$ and $\underline{S} \le s \le \bar{S}$, we determine how inflation varies with changes in SDS and SKS.

For given μ and s, the inflation rate between period 0 and period 1, $\Delta p(\mu, s)$, is given by equation (7) with the new distribution function for period 1 shocks, $G(q_1; \mu, s)$, replacing the earlier distribution function $\Phi(q_1; SDS)$ and with $F(q)$ given by equation (13) rather than by equation (6) as it was previously.

Moments of industry price changes for the model are calculated as they were for the previous model. Using the new distribution functions, we use the terms in the inflation equation (equation (7)) for the aggregate price change and for the behaviour of the four groups of firms that change their output prices in period 1. Then, the dispersion (standard deviation) of industry price changes, SDP, is given by equation (8), while the skewness of industry price changes, SKP, is given by

$$SKP = E\left(\Delta p_1^i - \Delta p_1\right)^3 / SDP^3, \tag{14}$$

where, as before, the expectation is over all industries i. Parameter values $\alpha = 0.975$, $-0.0167 \le \mu_1 \le 0.0167$, $0.02 \le s_1 \le 0.05$, $s_2 = 0.05$ are chosen to match features of the Australian data and then the two OLS regressions in the text, equation (2), are estimated.[29]

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[29] As before, $C = \{0.125\}$ is assumed. Recall that aggregate industry price inflation 1970-92 averages 8% p.a., while the dispersion across industries of (non-overlapping) six-monthly log price changes averages $SDP = 0.038$ over the sample and has a standard deviation (across time periods) of 0.018. Note further, that the skewness of the distribution across industries of these six-monthly log price changes averages $SKP = 0.41$ over the sample and has a standard deviation (across time periods) of 2.6. Imposing the parameter values in the text, when $\pi = 0.04$ per period (8% p.a.), and m and s vary uniformly over their allowed ranges, the standard deviations of both the dispersion of price changes, SDP, and the skewness of price changes, SKP, derived from the model match the Australian data values above.

Figure 1: Annual Consumer and Producer Price Inflation in Australia

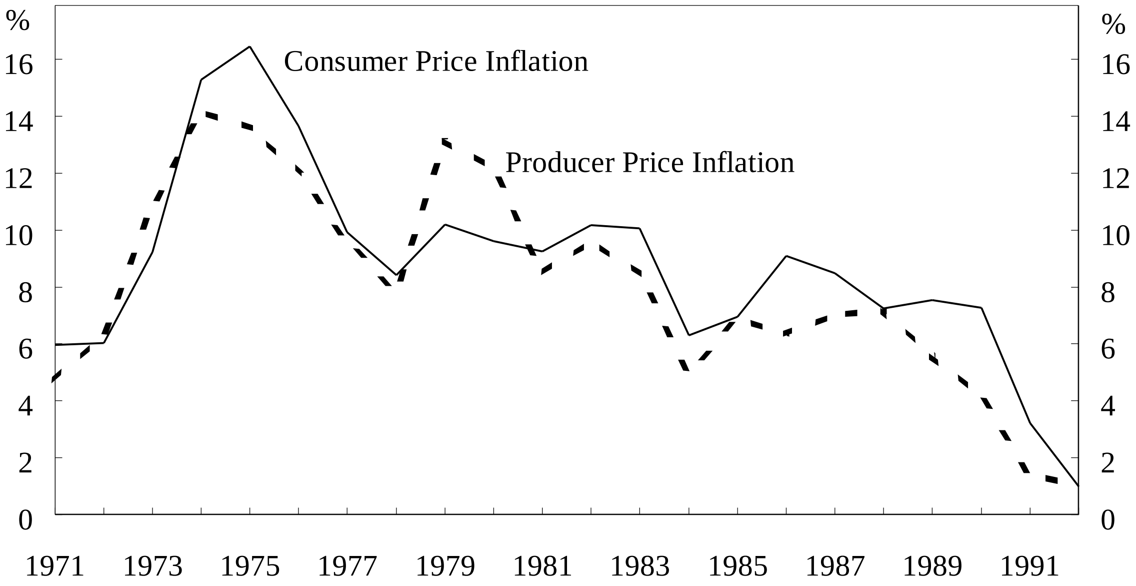
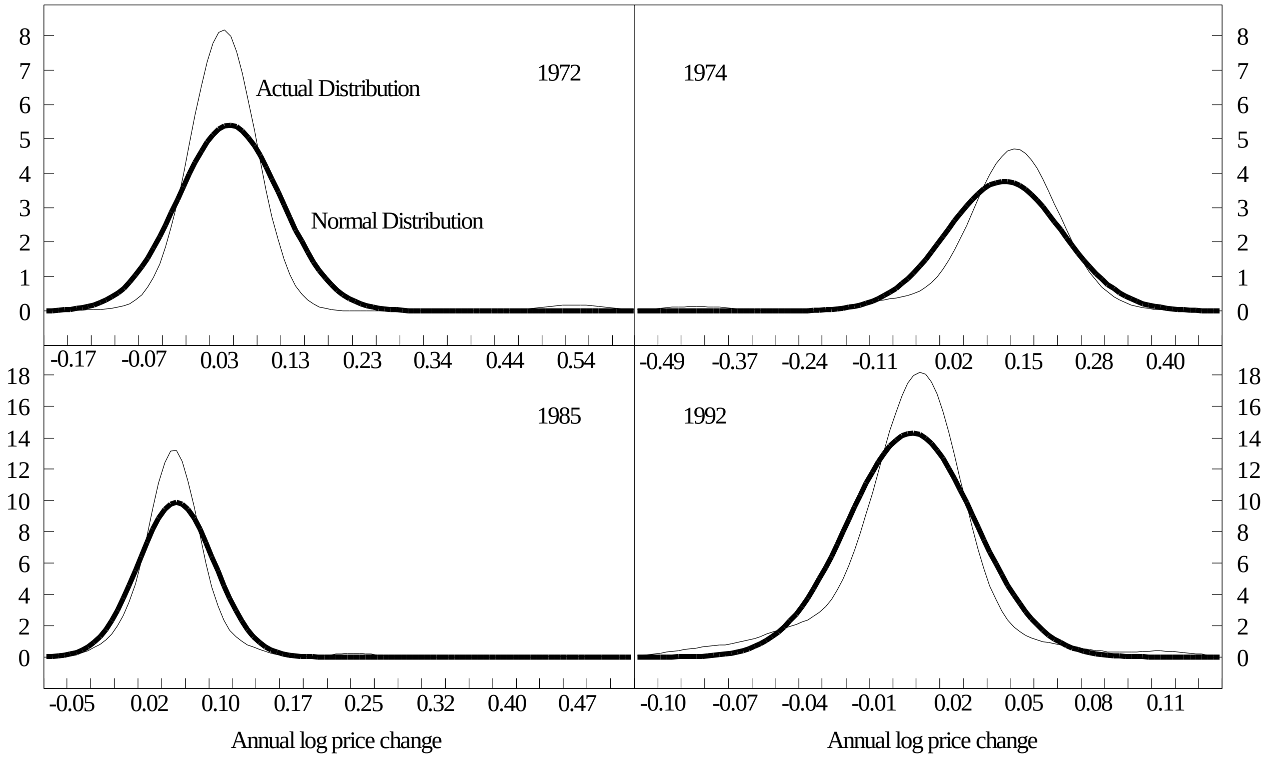
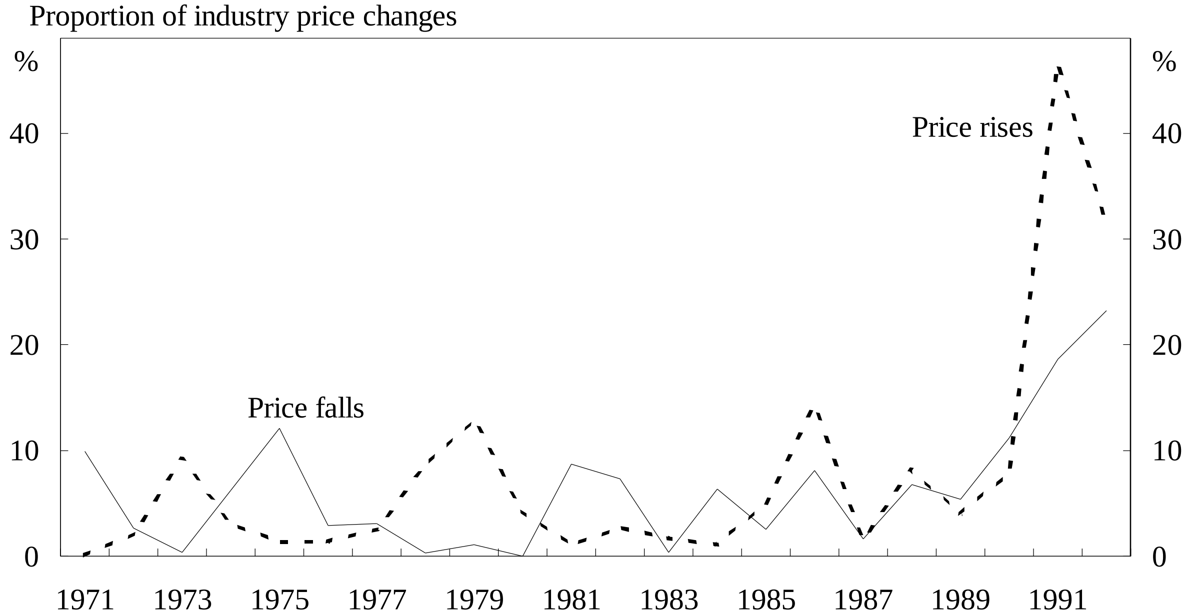


Figure 2



8
7
6
5
4
3
2
1
0
Actual Distribution
Normal Distribution
1972
1974
-0.17 -0.07 0.03 0.13 0.23 0.34 0.44 0.54
-0.49 -0.37 -0.24 -0.11 0.02 0.15 0.28 0.40
18
16
14
12
10
8
6
4
2
0
1985
1992
-0.05 0.02 0.10 0.17 0.25 0.32 0.40 0.47
-0.10 -0.07 -0.04 -0.01 0.02 0.05 0.08 0.11
Annual log price change
Annual log price change

Figure 3: Proportion of Price Falls and Price Rises



"Price falls" is the proportion of price falls in each year.
"Price rises" is the proportion of price rises greater than twice the producer price inflation rate in that year.

Figure 4: Firms' Optimal Nominal Price (ONP) with Expected Trend Inflation.

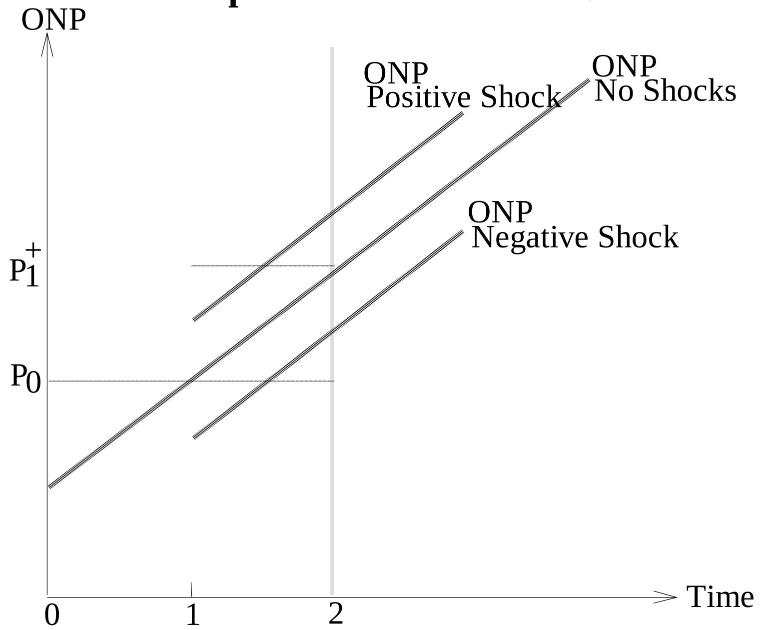


Figure 5: Inflation and the Economy-wide Dispersion of Shocks
(See equation (1) in text)

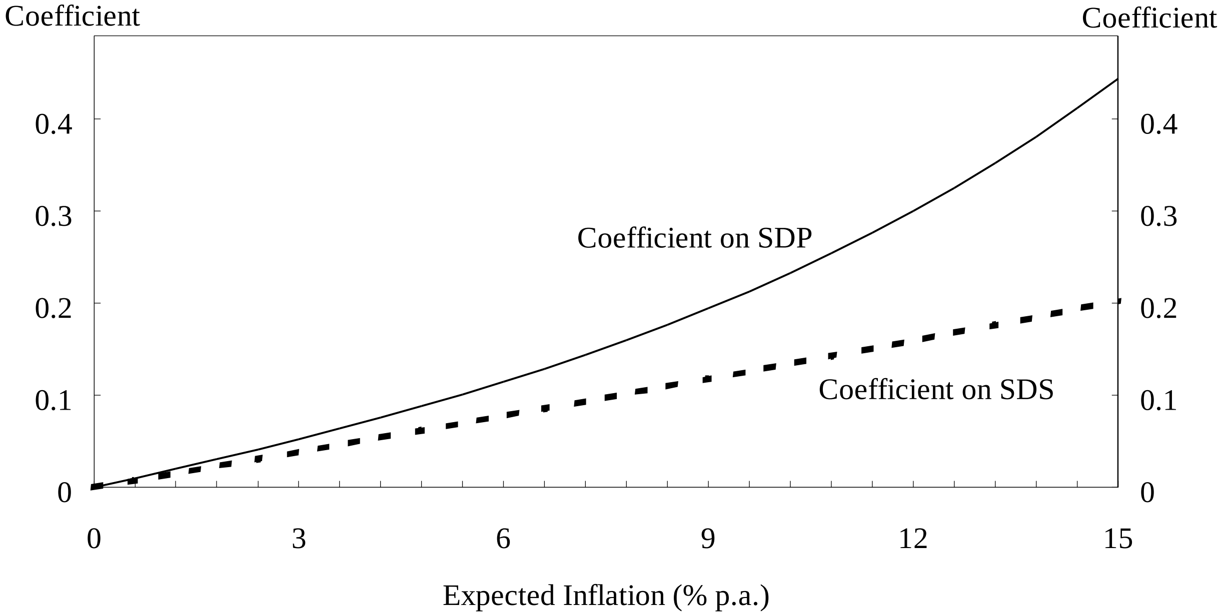


Figure 6: Model Results for the Regression of Inflation on the Standard Deviation and Skewness of Shocks
(See equation (2) in text)

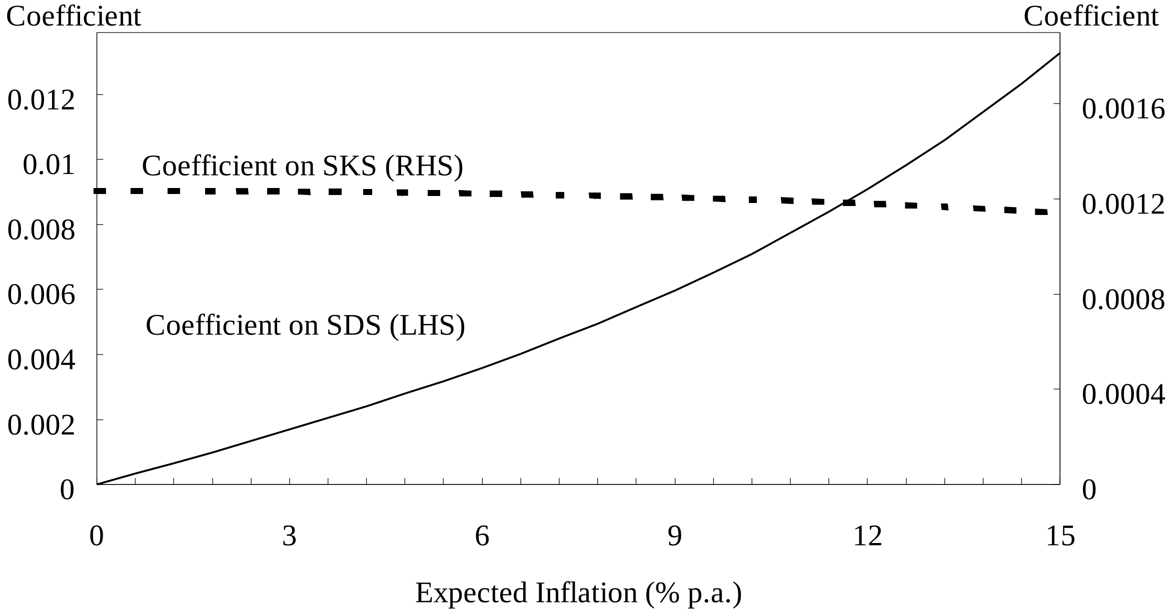


Figure 7: Model Results for the Regression of Inflation on the Standard Deviation and Skewness of Industry Price Changes
(See equation (2) in text)

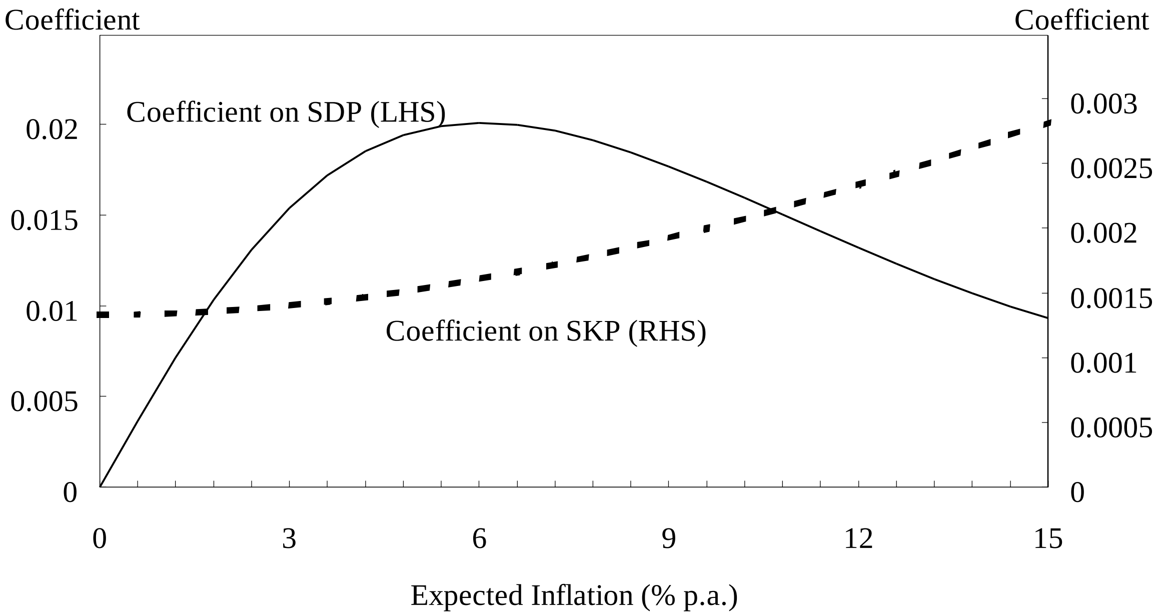


Table 1: Moments of Industry Price Changes - Annual Data

(Moments of log differences of prices)

	Aggregate Producer Price Inflation	Standard Deviation of Industry Price Changes	Skewness of Industry Price Changes
1971	0.047	0.048	-2.816
1972	0.063	0.074	5.918
1973	0.108	0.103	3.594
1974	0.142	0.106	-3.194
1975	0.136	0.094	-1.480
1976	0.120	0.048	-1.638
1977	0.096	0.040	-1.486
1978	0.078	0.040	0.911
1979	0.131	0.097	1.714
1980	0.121	0.052	1.885
1981	0.085	0.050	-1.553
1982	0.096	0.053	-0.333
1983	0.084	0.027	1.635
1984	0.050	0.027	-1.292
1985	0.069	0.040	4.850
1986	0.064	0.066	-1.278
1987	0.070	0.032	2.655
1988	0.072	0.054	1.597
1989	0.056	0.038	-1.304
1990	0.041	0.054	-1.716
1991	0.014	0.047	-3.476
1992	0.010	0.028	-0.008
Mean	0.080	0.055	0.145
Standard Deviation	0.037	0.025	2.567
Correlation between Skewness and Standard Deviation			0.053

Table 1 (cont.): Moments of Industry Price Changes - Six Monthly Data
(Moments of log differences of prices)

	Aggregate Producer Price Inflation	Standard Deviation of Industry Price Changes	Skewness of Industry Price Changes
Dec-70	0.013	0.041	-3.189
Jun-71	0.025	0.026	-2.197
Dec-71	0.031	0.019	-0.214
Jun-72	0.029	0.038	5.395
Dec-72	0.036	0.067	6.351
Jun-73	0.051	0.073	5.107
Dec-73	0.076	0.105	4.189
Jun-74	0.062	0.057	-2.956
Dec-74	0.085	0.080	-2.113
Jun-75	0.065	0.049	-1.317
Dec-75	0.060	0.041	0.552
Jun-76	0.065	0.023	0.329
Dec-76	0.049	0.036	-1.992
Jun-77	0.054	0.030	-0.996
Dec-77	0.035	0.027	-0.892
Jun-78	0.035	0.027	1.500
Dec-78	0.052	0.046	2.112
Jun-79	0.066	0.069	1.984
Dec-79	0.077	0.046	0.936
Jun-80	0.062	0.035	2.009
Dec-80	0.043	0.032	-1.716
Jun-81	0.044	0.028	-1.225
Dec-81	0.039	0.024	-0.733
Jun-82	0.047	0.038	-1.652
Dec-82	0.059	0.029	1.408
Jun-83	0.041	0.020	1.728
Dec-83	0.028	0.022	0.100
Jun-84	0.023	0.021	-1.755
Dec-84	0.027	0.013	1.473
Jun-85	0.034	0.023	1.296
Dec-85	0.041	0.044	6.461
Jun-86	0.024	0.045	-2.312
Dec-86	0.038	0.048	-1.077
Jun-87	0.033	0.029	1.035
Dec-87	0.035	0.030	1.109
Jun-88	0.038	0.037	3.534
Dec-88	0.031	0.037	1.314
Jun-89	0.027	0.026	-0.374
Dec-89	0.027	0.027	-1.147
Jun-90	0.017	0.030	-3.255
Dec-90	0.021	0.066	-2.656
Jun-91	0.001	0.034	-2.027
Dec-91	0.005	0.039	3.844
Jun-92	0.002	0.023	2.575
Dec-92	0.011	0.024	-1.930
Mean	0.039	0.038	0.414
Standard Deviation	0.020	0.018	2.566
Correlation between Standard Deviation and Skewness			0.241

Table 2: Inflation and Moments of Industry Price Changes

Dependent Variable: Annual Price Inflation

	Inflation Lagged 1 Year	Standard Deviation	Skewness	$\overline{R}^2$	Spec. Test p-values
United States					
1949-69 Ave.Inf. = 1.3%pa	**-0.18** (0.21)			-0.01	0.01 {0.48}
	-0.14 (0.22)	**-0.24** (0.46)		-0.05	0.011 {0.17}
	0.11 (0.23)	**-0.11** (0.42)	**0.007*** (0.003)	0.15	0.013 {0.80}
1970-89 Ave.Inf. = 5.7%pa	**0.67**** (0.17)			0.42	0.04 {0.40}
	0.48* (0.20)	**0.53** (0.30)		0.48	0.15 {0.30}
	0.39* (0.14)	**0.69**** (0.22)	**0.014**** (0.003)	0.73	0.62 {0.89}
Australia					
1972 - 92 Ave.Inf. = 8%pa	**0.83**** (0.16)			0.57	0.43 {0.48}
	0.73** (0.10)	**0.74**** (0.14)		0.82	0.77 {0.71}
	0.83** (0.09)	**0.70**** (0.12)	**0.004**** (0.001)	0.88	0.001 {0.503}

Notes: Data are annual. All regressions include a constant term (not shown). OLS standard errors in brackets. *(**) implies that the coefficient estimate is significantly different from zero at the 5%(1%) level. The specification test p-values reported are for the Breusch Godfrey test for the presence of first to second order serial correlation. p-values in {} are for the test of heteroscedasticity, formulated as $\hat{u}_t^2 = a + b_1 \hat{y}_t + b_2 \hat{y}^2_t$, where u_t are errors and y_t the dependent variable. The reported p-value is on the test that $\beta_1 = \beta_2 = 0$, with the null of homoscedastic error variances.

Table 3: Changes in Inflation and Moments of Industry Price Changes

Dependent Variable: Changes in Annual Price Inflation

	Lagged Changes in Inflation	Standard Deviation	Skewness	$\overline{R}^2$	Spec.Tests p-values
United States					
1949-69 Ave.Inf. = 1.3%pa	**-0.77** [0.01]			0.47	0.001 {0.00}
	-0.90 [0.01]	**-0.91** (0.53)		0.54	0.001 {0.002}
	-0.89 [0.01]	**-0.32** (0.52)	**0.006*** (0.002)	0.66	0.003 {0.015}
1970-89 Ave.Inf. = 5.7%pa	**-0.14** [0.08]			0.22	0.33 {0.49}
	-0.33 [0.08]	**0.19** (0.33)		0.18	0.62 {0.46}
	-1.04 [0.03]	**0.53** (0.29)	**0.014*** (0.005)	0.46	0.45 {0.93}
Australia					
1972 - 92 Ave.Inf. = 8%pa	**-0.33** [0.51]			-0.03	0.05 {0.79}
	-0.74 [0.11]	**0.70**** (0.22)		0.37	0.39 {0.97}
	-0.46 [0.05]	**0.71**** (0.13)	**0.006**** (0.001)	0.78	0.17 {0.94}

Notes: Data are annual. All regressions include a constant term (not shown). OLS standard errors in brackets. *(**) implies that the coefficient estimate is significantly different from zero at the 5%(1%) level. The specification test p-values reported are for the Breusch Godfrey test for the presence of first to second order serial correlation. p-values in {} are for the previously specified test for heteroscedasticity. Coefficients reported on the lagged changes in inflation are the sum of the coefficients on the first three lags. The corresponding test statistic, [ ], is the p-value on the test that the coefficients are all equal to zero.

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Table 6: Inflation and the Moments of Industry Price Changes: Six Monthly Data

Dependent Variable: Six Monthly Price Inflation
1970 - 1992
Annual Average = 8%pa

Inflation Lagged 6 Months	Standard Deviation	Skewness	Unemploy. Rate	$\overline{R}^2$	Spec. Test p-values
0.82** (0.09)				0.65	0.54 {0.15}
0.73** (0.08)	**0.35**** (0.08)			0.75	0.84 {0.74}
0.75** (0.08)	**0.32**** (0.09)	**0.0008** (0.0006)		0.76	0.52 {0.86}
0.74** (0.08)	**0.36**** (0.09)		**0.0003** (0.0014)	0.75	0.82 {0.74}
0.75** (0.08)	**0.31**** (0.09)	**0.0008** (0.0007)	**-0.0003** (0.0015)	0.75	0.53 {0.86}

Notes: Data are non overlapping, six monthly. The unemployment rate is the Hodrick-Prescott filtered unemployment rate, $\lambda = 1600$. All regressions include a constant term (not shown). OLS standard errors in brackets. *(**) implies that the coefficient estimate is significantly different from zero at the 5%(1%) level. The specification test p-values reported are for the Breusch Godfrey test for the presence of first to second order serial correlation. p-values in {} are for the previously specified test for heteroscedasticity.

Table 7: Inflation and the Moments of Industry Price Changes: Six Monthly Data

Dependent Variable: Six Monthly Price Inflation
1970 - 1992
Annual Average = 8%pa

Inflation Lagged 6 Months	Standard Deviation	St.Dev. *x* Past Annual Inflation	Skewness	$\overline{R^2}$	Spec. Test p-values
0.73** (0.08)	**0.35**** (0.08)			**0.75**	0.84 {0.74}
0.46** (0.11)		**4.34**** (0.91)		**0.77**	0.78 {0.71}
0.75** (0.08)	**0.32**** (0.08)		**0.0008** (0.0006)	**0.76**	0.52 {0.86}
0.50** (0.10)		**4.09**** (0.87)	**0.0013*** (0.0006)	**0.80**	0.77 {0.90}
0.40* (0.17)	**-0.16** (0.21)	**5.73*** (2.28)	**0.0015*** (0.0006)	**0.79**	0.63 {0.86}

Notes: Data are non overlapping, six monthly. All regressions include a constant term (not shown). OLS standard errors in brackets. *(**) implies that the coefficient estimate is significantly different from zero at the 5%(1%) level. The specification test p-values reported are for the Breusch Godfrey test for the presence of first to second order serial correlation. p-values in {} are for the previously specified test for heteroscedasticity.

Table 8: Standard Deviation of Industry Price Changes and the Terms of Trade

Dependent Variable: Standard Deviation of Six Monthly Industry Price Changes (Δ_2p)			
	Δ_2TOT	AbsΔ_2TOT	$\overline{R}^2$
Pre Float 1970:3 - 84:2	**0.083** (0.083)		0.023
		0.23** (0.06)	0.14
Post Float 1984:3 - 92:4	**-0.11** (0.08)		0.048
		0.28** (0.10)	0.15

Dependent Variable: Standard Deviation of Annual Price Changes (Δ_4p)			
	Δ_4TOT	AbsΔ_4TOT	$\overline{R}^2$
Pre Float 1971:1 - 84:4	**0.15** (0.11)		0.12
		0.37** (0.08)	0.39
Post Float 1985:1 - 92:4	**-0.076** (0.055)		0.074
		0.19* (0.08)	0.19

Notes:Data are quarterly. All regressions include a constant (not shown). $\Delta_x TOT = \ln(TOT_t/TOT_{t-x})$, where x is two for six monthly price changes and four for annual price changes and AbsΔ_xTOT is the absolute value of Δ_xTOT. Newey West standard errors, calculated using six lags, reported in brackets. *(**) implies that the coefficient estimate is significantly different from zero at the 5%(1%) level.

Table 9: Testing the Exogeneity of the Standard Deviation of Industry Price Changes

Dependent Variable: Change in Annual Inflation (annual data)

	Lagged Changes in Inflation	Standard Deviation	Skewness	$\overline{R}^2$	Hausman Test p-value
IV[a]	**-0.30** [0.23]	**0.43** (0.41)	**0.006**** (0.001)	0.70	0.48
OLS	**-0.460** [0.046]	**0.71**** (0.13)	**0.006**** (0.001)	0.78	

Dependent Variable: Six Monthly Inflation (six monthly data)

	Inflation Lagged One Period	Standard Deviation	St.Dev.*x* Past Annual Inflation	Skewness	$\overline{R}^2$	Hausman Test p-value
IV[a]	**0.79**** (0.10)	**0.17** (0.23)		**0.0011** (0.0008)	0.74	0.50
OLS	**0.75**** (0.08)	**0.32**** (0.09)		**0.0008** (0.0006)	0.76	
IV[b]	**0.40** (0.23)	**-0.38** (0.39)	**6.49** (3.37)	**0.002*** (0.0008)	0.77	0.74
OLS	**0.40*** (0.17)	**-0.16** (0.21)	**5.73*** (2.28)	**0.0015*** (0.0006)	0.79	

Notes:All regressions include a constant term (not shown). Standard errors in brackets - *(**) implies that the coefficient estimate is significantly different from zero at the 5%(1%) level. Coefficients reported on the lagged changes in inflation are the sum of the coefficients on the first three lags. The corresponding test statistic, [], is the p-value on the test that the coefficients are all equal to zero. The final column reports the Hausman test p - value for the null that the instrumented variable(s) is (are) exogenous.

a. The contemporaneous absolute value of the change in the terms of trade is used as an instrument for the standard deviation.

b. The contemporaneous absolute value of the change in the terms of trade, and the product of the absolute value of the change in the terms of trade and past annual inflation, are used as instruments for both the standard deviation and the product of the standard deviation and past annual inflation.

REFERENCES

Ball, Laurence and N. Gregory Mankiw (1992a), "Asymmetric Price Adjustment and Economic Fluctuations", NBER Working Paper 4089.

Ball, Laurence and N. Gregory Mankiw (1992b), "Relative-Price Changes As Aggregate Supply Shocks", NBER Working Paper 4168.

Blinder, Alan S. (May 1991), "Why are Prices Sticky? Preliminary Evidence From An Interview Survey", *American Economic Review*, 81, pp. 89-96.

Cecchetti, Stephen G. (April 1986), "The Frequency of Price Adjustment: A Study of the Newsstand Prices of Magazines, 1953-1979", *Journal of Econometrics*, 20, pp. 255-274.

Fischer, Stanley (1981), "Relative Shocks, Relative Price Variability, and Inflation", *Brookings Papers on Economic Activity*, 2, pp. 381-431.

Gruen, David W. R. and Geoffrey Shuetrim (1994), "Internationalisation and the Macroeconomy", *International Integration of the Australian Economy*, eds. P. Lowe and J. Dwyer, Reserve Bank of Australia.

Hausman, J. A. (1978), "Specification Tests in Econometrics", *Econometrica*, 46, pp. 1251-1271.

Kahneman, D., J.L. Knetsch and R. Thaler (1986), "Fairness as a Constraint on Profit Seeking: Entitlements in the Market", *American Economic Review,* 76, pp. 728-41.

Lebow, David E., John M. Roberts and David J. Stockton (1992), "Economic Performance Under Price Stability", Working Paper No. 125, Economic Activity Section, Board of Governors of the Federal Reserve System.

Sheshinski, Eytan and Yoram Weiss (1977), "Inflation and Costs of Price Adjustment", *Review of Economic Studies*, 44, pp. 287-303.

Tobin, James (1972), "Inflation and Unemployment", *American Economic Review,* 62, pp. 1-18.

Table 4: Inflation Regressions Including Unemploymen

Dependent Variable: Annual Price Inflation	Inflation Lagged 1 Year	Unemployment Rate	Standard Deviation	Skewness	$\overline{R^2}$
United States					
1949-69 Ave.Inf. = 1.3%pa	**-0.24** (0.22)	**-0.01** (0.006)	**-0.07** (0.44)		0.08
	0.008 (0.205)	**-0.011*** (0.005)	**0.09** (0.38)	**0.007*** (0.003)	0.34
1970-89 Ave.Inf. = 5.7%pa	**0.73**** (0.17)	**-0.019**** (0.006)	**0.35** (0.24)		0.67
	0.57** (0.15)	**-0.012*** (0.005)	**0.53*** (0.20)	**0.011**** (0.003)	0.79
Australia					
1972 - 92 Ave.Inf. = 8%pa	**0.71**** (0.11)	**0.003** (0.003)	**0.81**** (0.15)		0.82
	0.81** (0.09)	**0.002** (0.003)	**0.74**** (0.13)	**0.004**** (0.001)	0.88

Notes: Data are annual. The unemployment rate is adjusted by the Hodrick-Prescott filtered unemploymen regressions include a constant term (not shown). OLS standard errors in brackets. *(**) implies that the significantly different from zero at the 5%(1%) level. The specification test p-values reported are for th for the presence of first to second order serial correlation. p-values in {} are for the previo heteroscedasticity.

Table 5: Change in Inflation Regressions Including Unemploy

Dependent Variable: Changes in Annual Price Inflation

	Lagged Change in Inflation	Unemployment Rate	Standard Deviation	Skewness	[illegible]
United States					
1949-69 Ave.Inf. = 1.3%pa	**-0.75** [0.03]	**-0.0046** [0.70]	**-0.89** (0.69)		0.
	-0.86 [0.03]	**-0.0034** [0.61]	**-0.15** (0.68)	**0.006*** (0.003)	0.
1970-89 Ave.Inf. = 5.7%pa	**-0.58** [0.14]	**-0.027** [0.008]	**0.40** (0.25)		0.
	-0.99 [0.23]	**-0.023** [0.046]	**0.54** (0.25)	**0.008** (0.005)	0.
Australia					
1972 - 92 Ave.Inf. = 8%pa	**-0.65** [0.22]	**0.0043** [0.705]	**0.69*** (0.34)		0.
	-0.47 [0.06]	**-0.0048** [0.57]	**0.74**** (0.14)	**0.008**** (0.002)	0.

Notes: Data are annual. The unemployment rate is adjusted by the Hodrick-Prescott filtered unemployment rate, include a constant term (not shown). OLS standard errors in brackets. *(**) implies that the coefficie different from zero at the 5%(1%) level. Coefficients reported on the lagged changes in inflation are the su first three lags. The coefficient on unemployment is the sum of coefficients on the contemporaneous corresponding test statistic, [ ], is the p-value on the test that the coefficients are all equal to zero. The reported are for the Breusch Godfrey test for the presence of first to second order serial correlation. previously specified test for heteroscedasticity.

Figure 2: Distribution of Industry Price Changes